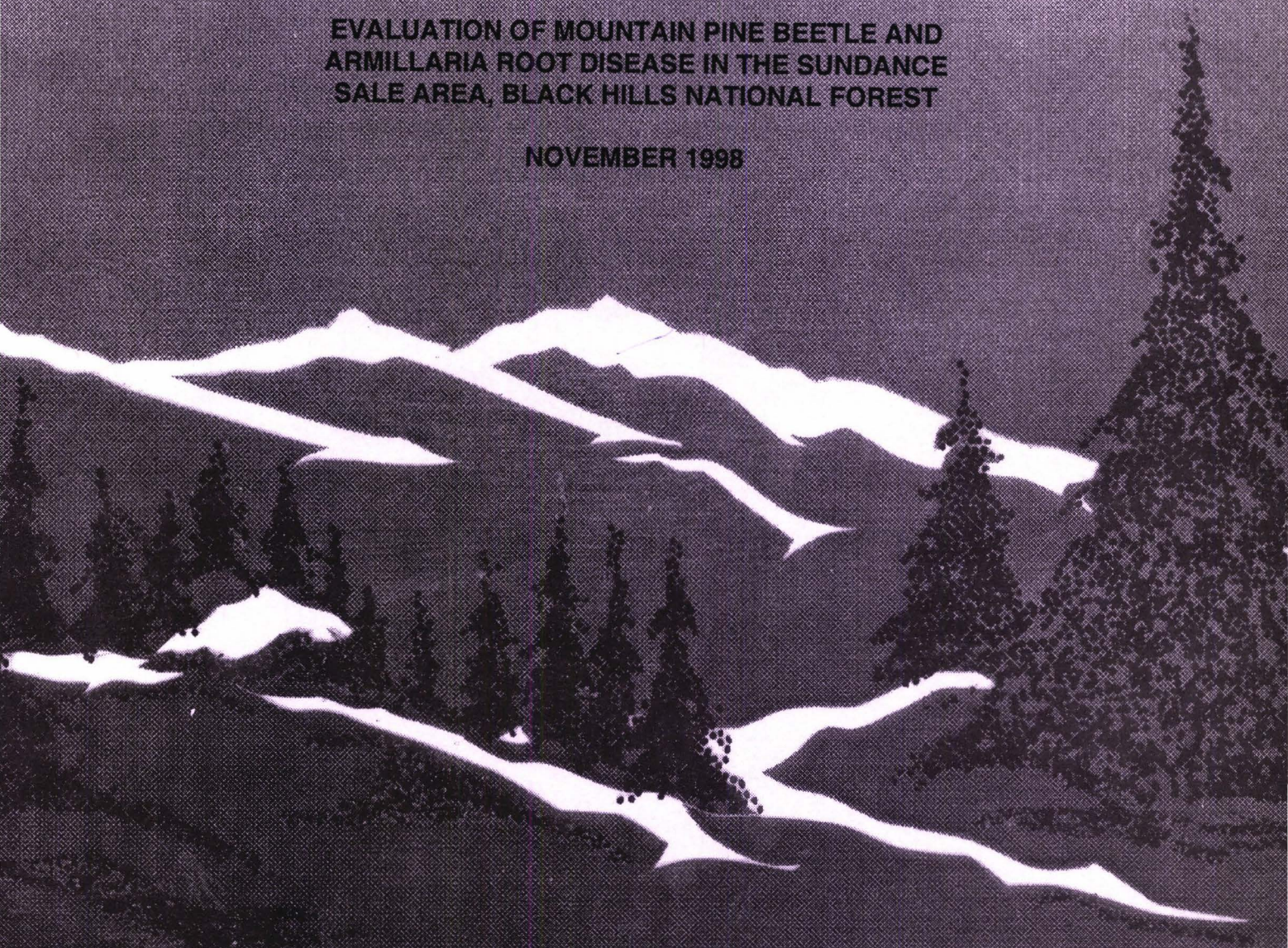
SB
761
.U9
R6
no.99-02

Forest Health Management

BIOLOGICAL EVALUATION
R2-99-02

EVALUATION OF MOUNTAIN PINE BEETLE AND ARMILLARIA ROOT DISEASE IN THE SUNDANCE SALE AREA, BLACK HILLS NATIONAL FOREST

NOVEMBER 1998



USDA United States Department of Agriculture

Renewable Resources
Forest Health Management

Forest Service
Rocky Mountain Region
Denver, Colorado

BIOLOGICAL EVALUATION
R2-99-02

EVALUATION OF MOUNTAIN PINE BEETLE AND ARMILLARIA ROOT DISEASE IN THE SUNDANCE SALE AREA, BLACK HILLS NATIONAL FOREST

NOVEMBER 1998

PREPARED BY:

JOEL D. MCMILLIN
ENTOMOLOGIST
RAPID CITY SERVICE CENTER

KURT K. ALLEN
CENTER LEADER
RAPID CITY SERVICE CENTER

JERI LYN HARRIS
PLANT PATHOLOGIST
RAPID CITY SERVICE CENTER

APPROVED BY:

ROBERT D. AVERILL
GROUP LEADER
R2, FOREST HEALTH MANAGEMENT

Renewable Resources
USDA Forest Service
Rocky Mountain Region
740 Simms Street
Golden, CO 80401

JUL 15 2011

ABSTRACT

Populations of the mountain pine beetle were detected and evaluated in Sundance Timber Sale area on the Bear Lodge District of the Black Hills National Forest. Beetle caused mortality of ponderosa pine increased from 1996 to 1998, with much of the tree death being in concentrated areas. Ground survey results indicate that an average of about 1.7 trees per acre have been killed over the last 3 years. Much of this mortality is in green trees attacked in the summer of 1998; however, it seems that beetle populations have **not** reached epidemic levels. Nonetheless, mortality may continue to increase in this area in the coming years. Strategies for dealing with this situation include: do nothing, silvicultural treatments, sanitation/salvage harvesting, infested tree treatment and individual tree protection. The recommendation at this time is to use sanitation harvests to try and lessen beetle caused impacts in combination with continued long-term silvicultural treatments. In addition to tree mortality caused by bark beetles, *Armillaria* root disease also may be killing trees by itself or in conjunction with beetles. Further work is needed to determine the extent of root disease with in the sale area.

INTRODUCTION

Mountain Pine Beetle

The mountain pine beetle (*Dendroctonus ponderosae*) is the number one insect killer of pines in the western United States. It is a native insect whose hosts include most pine species in the west. In the Black Hills, it is a pest of ponderosa pine.

The mountain pine beetle (MPB) has one generation per year in the Black Hills. Adult beetles fly from previously infested and killed trees in July - August and attack green trees. The adults chew through the bark and construct galleries, along which eggs are laid. The eggs hatch and produce larvae, which feed under the bark, feeding on the phloem. The beetle can overwinter under the bark as larvae, pupae, or callow adults. The beetle finishes its maturation process in the spring and early summer and then produces the next generation of adults to attack green trees.

Populations of the mountain pine beetle are usually found at an endemic level, killing and reproducing in stressed or weakened trees, including lightning strikes. Less than one tree per acre per year killed is considered to be an endemic level. For reasons that are not completely understood, MPB populations can at times increase dramatically. The beetles go through an increasing stage (more than 1 tree per acre per year killed, but less than 10% of the stand affected over a 3 year period) and finally into an epidemic stage where 10% or more of the stand is affected in a 3 year period (Lessard 1982). In the epidemic stage, healthy trees are attacked and killed along with stressed trees.

The beetle has always been a part of the Black Hills forest ecosystem, with outbreaks occurring periodically. The first recorded outbreak occurred from the late 1890's through the early 1900's and killed an estimated 1-2 billion board feet of timber. Other outbreaks have occurred in the 1930's, 1940's, 1960's and 1970's, each lasting 8-13 years and each one being more severe than the previous. The most recent outbreak occurred from 1988-1992 in the Bearhouse Area on the Harney Ranger District and ended up killing over 50,000 trees (Pasek and Schaupp 1992). Outbreaks of the beetle can cause considerable changes in forested stands, including a reduction in average stand diameter and stand density (McCambridge et al. 1982). Mortality levels of 25% can be expected throughout the landscape surrounding outbreak areas and levels of up to 50% can occur in heavily attacked stands (McCambridge et al. 1982). The levels of mortality caused in an epidemic and the associated change in stand structure and composition can be undesirable: it reduces timber stocking levels, perhaps to the point of being an understocked stand, can affect wildlife habitat, can increase short term fire risks, and can negatively effect visual and recreation values.

Pine stands in the Black Hills can be rated as to their susceptibility to MPB. Generally stands are considered to be most susceptible when 75% of the stand is in the 7-13 inch diameter range and the stand density is over 120 feet of basal area per acre (Stevens et al. 1980, Schmid and Mata 1992). It should be noted that these general hazard rating guidelines and most stand inventory data are based on stand averages; small pockets that have

high stocking levels within a low density stand can be a focal point for beetle buildup. Stand hazard ratings are indicators of which stands are most likely to have the initial beetle infestations. Once an outbreak has started, any stands containing suitable host material can incur damage. These ratings also give no indication of local beetle pressure. What hazard rating can provide is some answers as to which stands should be given priority in treatment to minimize beetle susceptibility. It also points out the best approach to reducing losses to the mountain pine beetle is forest management to reduce stocking densities. Aerial surveys done yearly in August on the Black Hills National Forest have been used to detect pines that have recently been killed by the MPB. For the past few years, beetle mortality has been light and scattered, with the 1996 survey finding the lowest level of beetle mortality in 20 years. However, the 1997 and 1998 surveys detected an approximate doubling in tree mortality each year.

Armillaria Root Disease

Armillaria root disease (causal agent *Armillaria ostoyae*) has not been well studied in the Bear Lodge Ranger District of the Black Hills. Most of the information we have about *Armillaria* comes from work that was done in the Northern Black Hills; perhaps similar comparisons can be made between the two areas.

Armillaria is often found on beetle killed trees in the Northern Black Hills. In an earlier survey, *Armillaria* spp. occurred on beetle killed trees with a 68% - 79% incidence of sampled trees (Lessard et al. 1985). There was a strong association between both mountain pine beetle and *Armillaria* root disease occurring on the same trees. The incidence of *Armillaria* is greater in the Northern Black Hills and appears to be more of an aggressive pathogen in the Northern area (Kallas et al. 1998).

It's possible that *Armillaria* is present on most sites of the Northern Hills, and is frequently attacking and attempting to infect roots. The trees defend themselves by producing resin and are able to prevent the root fungus from spreading on the root and colonizing more root tissue. All that the forest observer sees of this scenario are the resinous root lesions. However, when major stresses occur to the trees, such as beetle attack, then *Armillaria* is able to overcome tree defences and soon colonize the root tissues. There is even some evidence that the fungus can feed on the resin produced by the tree as a defence. If recently dead trees are examined for *Armillaria* in mountain pine beetle mortality pockets, the examiner will probably find extensive *Armillaria* that seems to be behaving aggressively. However, perhaps what the examiner is really seeing, is the opportunistic behavior of this fungus as it colonizes the roots after the tree's defenses have been lessened/weakened due to beetle attack (Wargo, 1984a; Wargo, 1984b, Wargo and Shaw, 1985).

METHODS

Mountain Pine Beetle

The current mountain pine beetle conditions for the Sundance Timber Sale area on the Bear Lodge Ranger District were estimated using two methods: Aerial survey data and strip cruises to estimate green infested trees.

The aerial survey was done in late August 1998. Fading trees were marked on a map. Areas that had high concentrations of faders were ground checked to determine causal agent and determine if more intense ground surveys were needed.

Strip cruises were initiated throughout the Sundance Timber Area in September and were completed by early October 1998. Each transect line was approximately 1 mile long and at least 1 chain wide, so each transect covered a minimum of 8 acres (except where noted). Along each transect line, recently killed trees were counted. Killed trees were broken into three categories:

New beetle hits-1998 (green trees),
One year old hits-1997,
Two year old hits-1996,
Current pitchouts.

A total of 8 transect lines were run, covering 8.75 miles (1 of the lines was 1.25 miles long and another was 1.5 miles) throughout the area of the sale, for a total of 70 acres evaluated. On each line variable radius prism (BAF 10) plots were measured every 1/4 mile, for a total of 4 per mile (5 on the line that was 1.25 miles and 6 on the line that was 1.5 miles). Diameter at breast height (DBH) were taken for all "in" trees in each plot. These measurements were used to provide a rough estimate of basal area and DBH along the cruise lines. The distribution of cruise lines in the sale area is shown in Figure 1.

Armillaria Root Disease

On 22 October 1998, areas within the sale were visited where Armillaria root disease had been observed while surveying for mountain pine beetle (Figure 1). Several trees were examined. Many trees were recently dead due to mountain pine beetle attack or were showing some decline with thinning and fading crowns; even a few healthy trees were examined for comparisons. Excavations were made around the root collars of the trees and at least one primary root. Bark was removed to view the characteristic white mycelial fans. Identifying mycelial fans to confirm Armillaria can be difficult. The Black Hills has some prolific decomposing fungi that also produce a cream colored mycelial fan under the bark. A tree's dead cambial tissue may look like *Armillaria* fans. Culture work is needed to confirm *Armillaria* spp. in some ambiguous samples. Resinous roots are good indicators of root lesions and may be symptomatic of recent infection attempts by *Armillaria*. Resinous roots may also just be abrasions by the rocky soil.

RESULTS

Mountain Pine Beetle

The aerial survey from 1997, which detected trees killed in 1996, found a total of 23 trees killed by mountain pine beetle within the Sundance Timber Sale area. Most of the trees detected were scattered and isolated groups of 1-2 trees. In 1998, the survey detected 63 trees killed in 1997 within the Sundance Timber Sale area. Although this resulted in an approximately 3-fold increase in mortality, there were few individual spots that contained more than 5 dead trees.

The strip cruises provided information on current levels of infestation in the area. Beetle populations and tree mortality have been increasing over the last two years, and may continue to increase in 1999 unless harvesting or sanitation actions are implemented. Table 1 lists the number of beetle killed or infested trees found from all transects done in the Sundance Timber Sale area. Mortality from the past 2 years plus this year's green infested trees indicate that there are an average 1.7 trees attacked per acre throughout the entire sale area. This should be considered an endemic population of MPB. Table 1 also includes a ratio of attack frequency among years, a measure of population buildup or decline between years. As is seen in Table 1, there are about 5 times as many green infested trees in 1998 as there were infested trees in 1996, but only about 2 times as many attacks 1998 compared with 1997. This indicates that beetle populations are continuing increasing in this area, but not at as fast as the previous year.

Table 2 lists the number of attacked trees by cruise line. Although there are some differences depending upon location, beetle populations are relatively low and generally scattered throughout sale area. The areas having the largest number of new infestations are on the east-central and southeastern portions of the sale (Figure 1). This is shown through both the cruise lines 1 and 4 and from the aerial survey data. The majority of the rest of the sale area seems to have a lower beetle population. The stand data from the variable radius plots collected along the cruise lines suggests that most of the area does not have particularly high basal areas and would be classified as areas of low susceptibility to future beetle attack based on the currently used hazard rating system for the Black Hills (Schmid et al. 1994). However, average tree diameters were large enough in all stands to be acceptable to the beetle (i.e., plot averages for all lines was greater than 12 inches).

Armillaria Root Disease

Armillaria was found in both of the two general areas of the timber sale that were examined (Figure 1). *Armillaria* occurred on several of the beetle killed trees. There were even a few dead trees found that had *Armillaria* and no signs of beetle attack. It is very likely that *Armillaria* is a contributing agent to the mortality of these trees. Many of the declining trees that were examined did not have well-developed fans, but contained several resinous lesions on the roots. It is also likely that dead trees identified in the aerial survey process as killed by mountain pine beetle included trees killed in part or instead by Armillaria root disease.

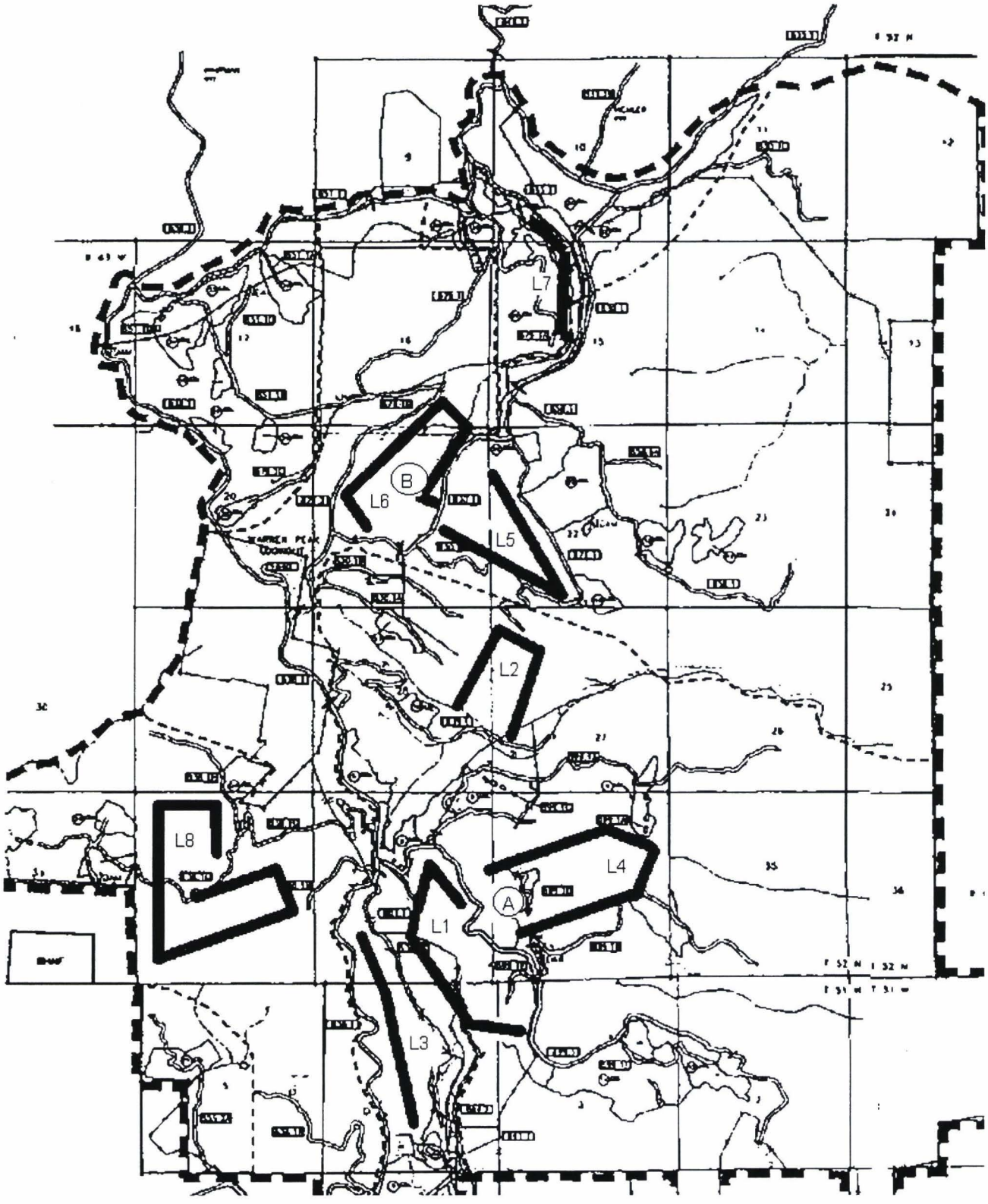


Figure 1. Cruise lines to detect mountain pine beetle relative to forest road system and location of Armillaria root disease sampling points (circled letters) in the Sundance Timber Sale.

Table 1. Number of mountain pine beetle attacked trees along 8.75 miles of cruise lines in the Sundance Timber Sale Area, Bear Lodge Ranger District and the ratio of attack frequency between years.

Number of Trees Attacked

Year	Total Trees Attacked (70 acres)	Attacked Trees Per Survey Line (8 acres)	Attacked Trees Per Acre
1996 Dead	14	1.8	0.2
1997 Dead	36	4.5	0.5
1998 Dead	51	6.4	0.8
1998 Pitchouts	13	1.6	0.2
All Attacks 1996-1998	114	14.3	1.7

RATIO OF ATTACK FREQUENCY BETWEEN YEARS

1996:1997 -- 1:2.7

1997:1998 -- 1:1.8

1996:1998 -- 1:4.8

Table 2. Number of trees attacked per acre by mountain pine beetle along with average tree diameters and basal area in the Sundance Timber Sale area, by cruise line.

Line	Location	Killed trees per acre, attacked in 1996	1997	1998	DBH	BA
1	West side of road 899.1	0.4	1.4	2.5	13.5	62.5
2	North and east sides of road 839.1	0.4	0.9	0.8	12.4	80.0
3	West side of road 838.1	0.0	0.1	0.3	12.5	87.5
4	North side of road 899.1B	0.0	0.9	1.3	12.7	82.5
5	North and east sides of road 830.1C	0.3	0.1	0.3	13.3	87.5
6*	South and east sides of road 879.1B	0.6	0.2	0.3	12.5	52.0
7	West side of road 841.1	0.0	0.1	0.3	13.7	75.0
8*	North and south sides of road 838.1G	0.1	0.5	0.5	13.4	68.3

*Line 6 was 1.25 miles long (covered 10 acres) and had 5 variable radius plots measured, and line 8 was 1.5 miles long (covered 12 acres) and had 6 variable radius plots measured.

CONCLUSIONS

Mountain Pine Beetle

The number of trees attacked and the buildup ratios for the entire area are typical for years of endemic MPB populations. For example, year-to-year attack ratios of 1:2 or 1:3 are characteristic of population buildups. However, for the entire Black Hills National Forest the number of trees attacked in 1 year has been as high as 26.8 per acre and buildup ratios greater than 10 on the Spearfish District in the beetle epidemic of the 1970's (Creasap and Minnemeyer 1976). In addition, areas east of Warren Peak on the Bear Lodge Ranger District experienced severe reductions in average basal area (e.g., 20 - 80 %) in the mid 1970's, when average pre-outbreak basal areas were higher than 240 square feet per acre (Creasap and Minnemeyer 1976).

The east-central and southeast portions of the Sundance Timber Sale (cruise lines 1 and 4) had more beetle activity and population build up than the rest of the sale area. Overall, it seems that this area is in the beginning stages of a mountain pine beetle increase. The attack ratio from 1996 to 1998 was approximately 1:5 and green infested trees were found in all areas of the Sundance Timber Sale. All infested trees that were examined had live brood in them, mostly larvae. A general observation from the ground surveys was that there was a fair amount of woodpecker activity in the area. Woodpeckers are a natural enemy of the beetles that eat the larvae as they are maturing under the bark. At this point it is unknown what percentage of the beetles will overwinter successfully; however, with the number of new attacks there should be plenty of new beetles to continue to fuel a population build up in 1998.

Armillaria Root Disease

The *Armillaria* root disease on these sites of the Sundance Timber Sale area may increase in aggressive behavior with the harvesting of the site. Tree wounding and soil compaction on the site may weaken a few residual trees and allow the *Armillaria* to cause mortality. The *Armillaria* inhabiting infected stumps may destroy some of the seedling/sapling regeneration, but probably will not hinder too much of the future stocking levels since the Black Hills seems to produce prolific regeneration. Further survey work could be done by our unit next field season, if forest managers need more information about the distribution and pathogenic behavior of the *Armillaria* on these sites.

ALTERNATIVES

Mountain Pine Beetle

There are a number of actions that can be used to reduce the impacts of mountain pine beetle in this area. These actions fall into two categories: direct action against the beetles themselves or indirect action which addresses the general stand conditions. Direct action deals with the symptoms, too many beetles in one place at one time and is aimed at

directly reducing the number of beetles present. Indirect action is aimed at the cause of the problem, which is stand conditions that are adequate for beetle buildup and outbreak.

The only effective long range strategy in minimizing beetle caused mortality is controlling stand conditions silviculturally over entire landscapes and constant monitoring for areas of beetle buildup.

Alternative 1: Do Nothing. Accept that MPB caused tree mortality and the impacts associated with it as a natural process. The future extent of the damage to the stands in this area and surrounding areas is difficult to estimate, but there will be changes in the forest caused by beetles.

Where to use: Use where other alternatives are not desired or cannot be used.

Advantages: There is no mechanical site disturbance. There will be an increase in the amount of light getting to the forest floor, so that understory species and regeneration may be enhanced. Habitat for some wildlife species may be enhanced due to decreasing crown closure and creation of standing dead trees.

Disadvantages: This alternative allows beetle populations to increase and spread to other trees and surrounding areas. There is a loss in timber revenues from either not harvesting beetle killed trees or letting the infestation grow and increasing the amount of killed timber. Fire hazards can increase with an increase in dead material, including red, dry needles. Visual and recreation values can be negatively affected. The loss of overstory tree cover can have a negative effect for some wildlife species. Regeneration can be impeded as dead trees fall and cover or shade the forest floor.

Alternative 2: Silvicultural Treatment. These are actions that increase tree vigor and reduce stand susceptibility to beetle attack. It is a preventative treatment that must be done prior to stands experiencing beetle outbreaks. In the Black Hills, stands that are under 80 square feet of basal area per acre with average stand diameters of under 7 inches are at the lowest risk. When treating stands care must be taken to avoid leaving pockets of dense trees in an otherwise thinned stand.

Where to use: This is a preventative and should be used regularly when planning timber harvests. It is not a tool in stands currently experiencing a beetle outbreak.

Advantages: Silvicultural treatment can reduce overall stand susceptibility to beetle infestation. It is not a guarantee that there will be no beetle caused mortality, it creates conditions that are less likely to experience a beetle outbreak. It maximizes the economic return from timber sales, as cutting is done prior to mortality taking place. The forest will experience mortality through time, treating stands silviculturally allows the decisions on what the forest will look like in the future through the types of harvesting done. If not, the beetles will

decide what the forest will look like in the future through their actions, and this may be considerably different than what is desired.

Disadvantages: This action is not suitable for areas where timber harvest is not feasible. In addition, there are site disturbances associated with timber harvest while the cutting is being done.

Alternative 3: Sanitation/Salvage Harvest. Sanitation harvesting involves removing currently infested pines prior to the beetles maturing and leaving to infest new trees. It requires the removal of green trees which have live brood in them. These green trees are already dead, however, the foliage will not change color until the following summer. Trees removed in a sanitation harvest are treated, either moved to at least one mile from the nearest live host type or processed at the mill, prior to beetle emergence. Salvage harvest involves the removal of beetle killed trees which do not have live beetles in them. These trees have already changed color, their needles are either red or gone.

Where to use: Stands susceptible to MPB that are currently under attack where it is desirable to reduce MPB populations and recover timber resource value. Also appropriate where beetle populations threaten currently uninfested nearby stands.

Advantages: MPB populations can be reduced in localized areas and in individual stands by removing most of the currently infested trees. This can provide some protection to surrounding uninfested trees and stands by removing a large source of attacking beetles. Timber values are recovered that would otherwise be lost or degraded. Fuel loading and fire hazard can be reduced by removal of much of the dead needles and timber. Regeneration can be enhanced through overstory removal and site disturbance.

Disadvantages: This alternative has a short implementation time. Areas must be marked and cut prior to beetle flight, July - early August in the Black Hills. Sanitation will not be effective on a large scale or for the long-term. It is only effective at suppressing beetles at the stand level and therefore will not work on a landscape level or when there is a chance of beetles reinfesting the treated area. Sanitation logging alone is only a temporary measure to reduce beetle populations and generally does not protect the treated stand for more than 3 or 4 years. Site disturbance that accompanies timber harvest occurs.

Alternative 4: Infested Tree Treatment. Cut and individually treat infested trees prior to beetle emergence. The action should kill most or all of the beetles within the cut trees. Examples of treatments include: cut and burn on site, cut and bury at least 6 inches on site, cut and chip, cut and debark, or cut and treat with a chemical insecticide.

Where to use: This is most appropriate for treating small spots in areas where high value resources are nearby. It can be used in areas that are unroaded or too steep for conventional sanitation or salvage harvesting.

Advantages: Beetle populations can be reduced or eliminated from the treated area. This can provide some relief to surrounding uninfested stands and trees. The site disturbance is less than in conventional harvesting operations. Regeneration can be enhanced through the removal of overstory trees. Fire hazard can be reduced.

Disadvantages: The implementation time for this alternative is short. Treatments must be done after new infested trees are located and prior to beetle flight. This treatment only reduces beetle pressure in a small area, it is not effective on a landscape scale. This treatment does nothing to address stand conditions that led to beetle buildup in the first place.

Alternative 5: Protection of High Value Trees. Prior to beetle emergence in the summer, the stems of high value trees are treated with a registered insecticide.

Where to use: On trees around residences and in campgrounds. Trees must be of significantly high value and be under heavy beetle pressure to justify treatment costs.

Advantages: This action is very effective at protecting individual trees from becoming infested.

Disadvantages: Insecticide application does not effectively reduce beetle populations or address the cause of the outbreak. It does not guarantee protection and application must be thorough for it to be effective. Many people have concerns regarding environmental contamination when using pesticides. It is extremely expensive and, therefore, is only appropriate for a single or a few high value trees.

RECOMMENDATION

Overall, MPB populations seem to be increasing within the Sundance Timber Sale area. Currently, the amount of mortality in this area is relatively low, but the population is building. The low basal area and low beetle population suggests that there is not a strong likelihood for a beetle outbreak for the areas surveyed. However, *Armillaria* root disease seems to be a problem that will be with the area for a long time. It can kill regeneration and can weaken trees to the point of making them more attractive to beetles. The present beetle situation seems to have arisen out of this type of stress, many of the beetle hit trees also appeared to have some root disease. If left to run its course, beetles could cause some additional mortality within the timber sale area in the next few years. At this time, the recommended course of action is alternative 3, sanitation/salvage harvest. This can be built into the current sale, it may require adding a small amount of volume to be removed to take out beetle infested trees that were marked as leave trees. It seems that the beetles are just getting started in much of the area and removal of as much infested material as possible prior to next summer's flight should help to effectively reduce the problem locally. It is a process that may require 2 to 3 years of scouting and tree removal to effectively reduce the population, but if started now, it could be a highly effective way to protect surrounding uninfested stands and trees while getting some return for the timber. Alternative 2, silvicultural treatments, is one that should continue to be built into long range planning efforts and can be used to guide the overall direction of where timber activities should occur. In addition, there should be continued MPB monitoring efforts, as it appears that the beetle is building in a number of different areas on the district. Early detection of possible problem areas allows the use of the widest range of treatment alternatives to deal with the problem. How to deal with *Armillaria* is not as clear. The only effective way to remove the inoculum from the site is to pull out stumps of trees that are cut. This is very costly and time consuming and not recommended for an area this big. At this time, the best course of action we can advise is to carry out the sale as planned and then do some monitoring, especially in the regeneration, for increased mortality caused by *Armillaria*.

REFERENCES

Creasap, V.L. and C.D. Minnemeyer. 1976. Mountain pine beetle, Black Hills of South Dakota and Wyoming, Black Hills National Forest and adjacent state and private lands of South Dakota and Wyoming. USDA Forest Service, Rocky Mountain Region, Biological Evaluation R2-76-8.

Kallas, M.A.; Reich, R.M.; and Jacobi, W.R. 1998. Stochastic Spatial Probability Model for Armillaria root disease in the Black Hills. In press.

Lessard, G. 1982. Factors affecting ponderosa pine stand susceptibility to mountain pine beetle in the Black Hills. USDA Forest Service, Rocky Mountain Region, Technical Report R2-26.

Lessard, G.; Johnson, D.W.; Hinds, T.E.; and Hoskins, W.H. 1985. Association of Armillaria root disease with mountain pine beetle infestations on the Black Hills National Forest, South Dakota. USDA Forest Service FPM MAG 85-4 pp 6.

McCambridge, W.F., F.G. Hawksworth, C.B. Edminster, & J.G. Laut. 1982. Ponderosa pine mortality resulting from a mountain pine beetle outbreak. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Paper RM-235.

Pasek, J.E. and W.C. Schaupp. 1992. Status and trends of mountain pine beetle populations in the Bear Mountain and White House Gulch areas of the Harney Ranger District, Black Hills National Forest, South Dakota. USDA Forest Service, Rocky Mountain Region, Biological Evaluation R2-92-04.

Schmid, J.M. and S.A. Mata. 1992. Stand density and mountain pine beetle-caused tree mortality in ponderosa pine stands. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Note RM-515.

Schmid, J.M., S.A. Mata and R.A. Obedzinski. 1994. Hazard rating ponderosa pine stands for mountain pine beetles in the Black Hills. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Note RM-529.

Stevens, R.E., W.F. McCambridge and C.B. Edminster. 1980. Risk rating guide for mountain pine beetle in Black Hills ponderosa pine. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Note RM-385.

Wargo, P.M. 1984a. Changes in phenols effected by *Armillaria mellea* in bark tissue of roots of oak, *Quercus* spp. pp 198-206 in Proc. IUFRO Conf. Root Butt Rots. For. Trees 6th G.A. Kile, Ed. CSIRO, Melbourne, Australia.

Wargo, P.M. 1984b. How stress predisposes trees to attack by *Armillaria mellea*, a hypothesis. pp 115-122 in Proc. IUFRO Conf. Root Butt Rots. For. Trees 6th G.A. Kile, Ed. CSIRO, Melbourne, Australia.

Wargo, P.M. and Shaw, C.G. III. 1985. Armillaria root rot: the puzzle is being solved. Plant Dis. 69: 826-832.